Noise and Antennas

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Introduction

Hi, welcome to the Aerospace Maker channel. I'm Aaron Harper. This channel is all about the nuts and bolts of aerospace. This week we were going to cover the communication link from the ground station antenna all the way through the system, but conversations have made it clear that we need to cover noise and antennas first. We'll pick up on the ground segment next week. If you have not seen this series' previous videos, I encourage you to view them to see how we arrived at these figures rather than take our word for it.

There will be a fair bit of details given, so please refer to the website, aerospacemaker.org for the transcript with the references. Should you get lost, don't panic. Replay the video a couple of times and dig a little deeper into the source material. That's what it is there for.

A Bit of a Review

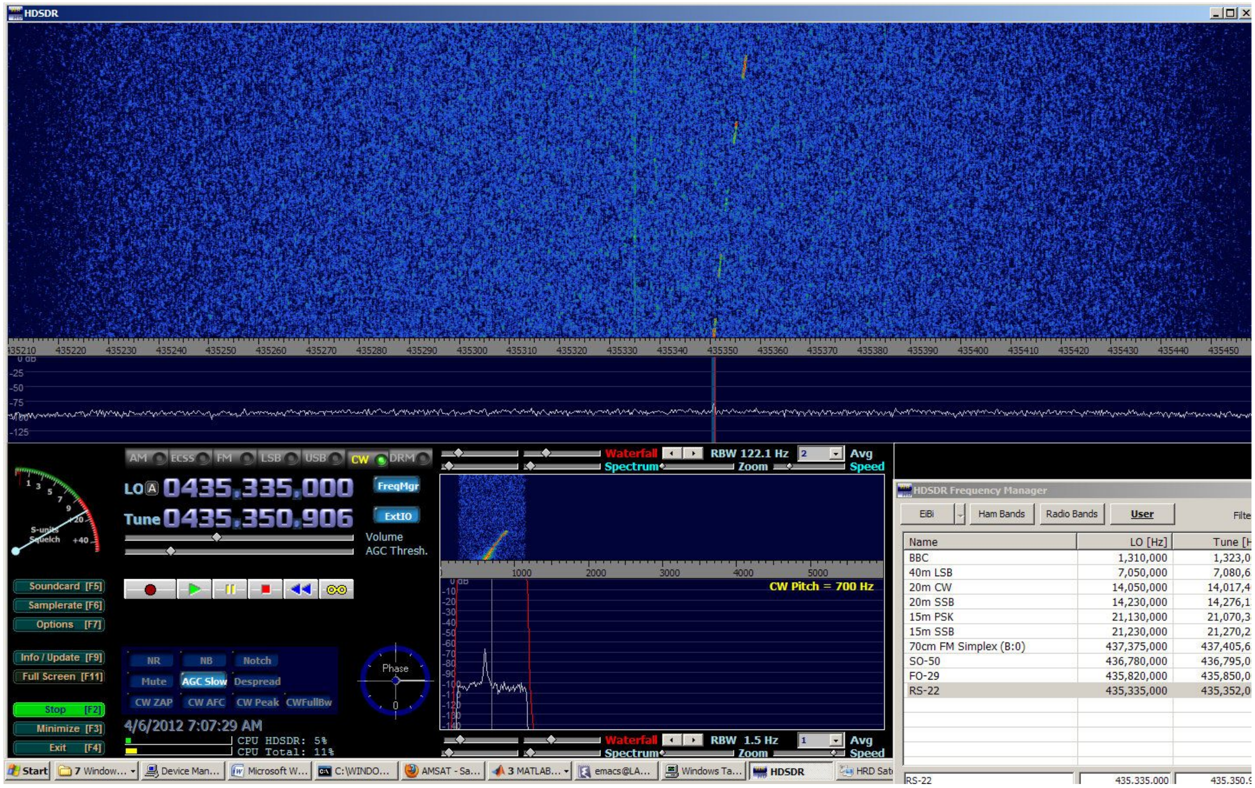
Let's review what we know so far. Our scenario is to receive the images from the NOAA-19 weather satellite, assuming our satellite is 60 degrees above the horizon, and at an altitude of 870 km above the surface of the earth transmitting at a frequency of 137.1 MHz. We also know that the satellite's output power is 12.45dBW estimate isotropic radiated power, or EIRP.

Last week we determined that our slant range is 985.192 kilometers, and this attenuates, or reduces, or signal by -135.06 dB. The atmosphere has an additional attenuation of -0.566, bringing the total loss to -135.626 db. When combined with the EIRP of the satellite, we get a signal level at the ground station of -123.176 dBW. This is not a strong signal, and we have the tools to make up for the losses, but there is more than just distance in our way.

Noise

Going back to last week's analogy of seeing a flashlight on a distant mountainside, while this signal is faint, it may well be detectable under the ideal conditions, such as at night and observed from inside a darkened room. What if it was during the day or the room were not darkened? We would not be able to see the flashlight because of all the extra light around us. The same thing happens in radio.

As if receiving a small signal isn't difficult enough, noise from various sources can make it like finding a needle in a haystack. The signal from NOAA-19 is very faint, and unless conditions are idea, or made to be as close to ideal as possible, we will not be able to gather enough signal to decode into a meaningful picture. Fortunately, there are tools to detect weak signals such as this waterfall display.



There is a satellite signal in the noise. It is the curved dashed line a little to the right of center of the waterfall display. This and other tools only show us the signal; it does not make the signal easier to receive.

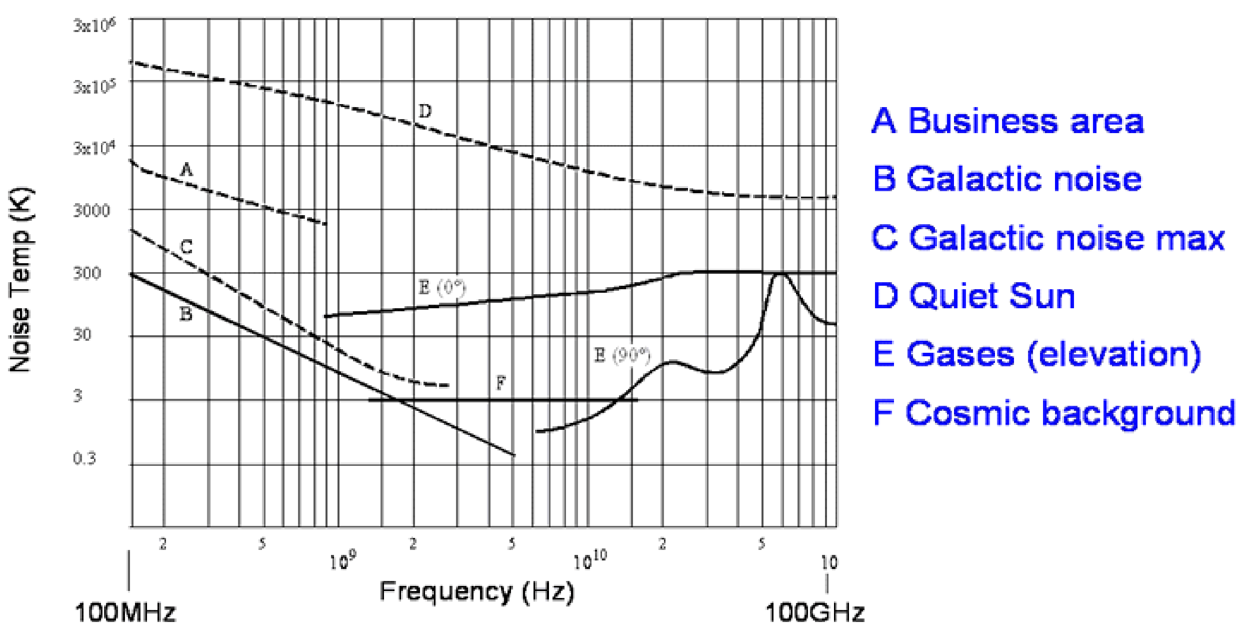
Understanding Noise

Noise is difficult to avoid, and reducing it while boosting the signal we want is tricky. We need to understand noise and its sources in order to mitigate it.

Simply put, noise is any signal which is unintended in transmission or reception. As such, it can be everything from a microwave oven, to a machine shop 2 miles away. It can also be our own sun, quasars in our galaxy, or even the earth itself. Besides the man made sources, any time atoms are in motion, they make noise. The more atoms, the more noise. Also, the more heat, the more motion, and thus, more noise. The measurement of noise is in Kelvin, the temperature measurement.

There are many sources of noise which interfere with our ability to bring in the weak signal. They are generally very broad across the frequency domain with the exception of interfering radio transmissions The following are sources with their anticipated levels, called noise temperature:

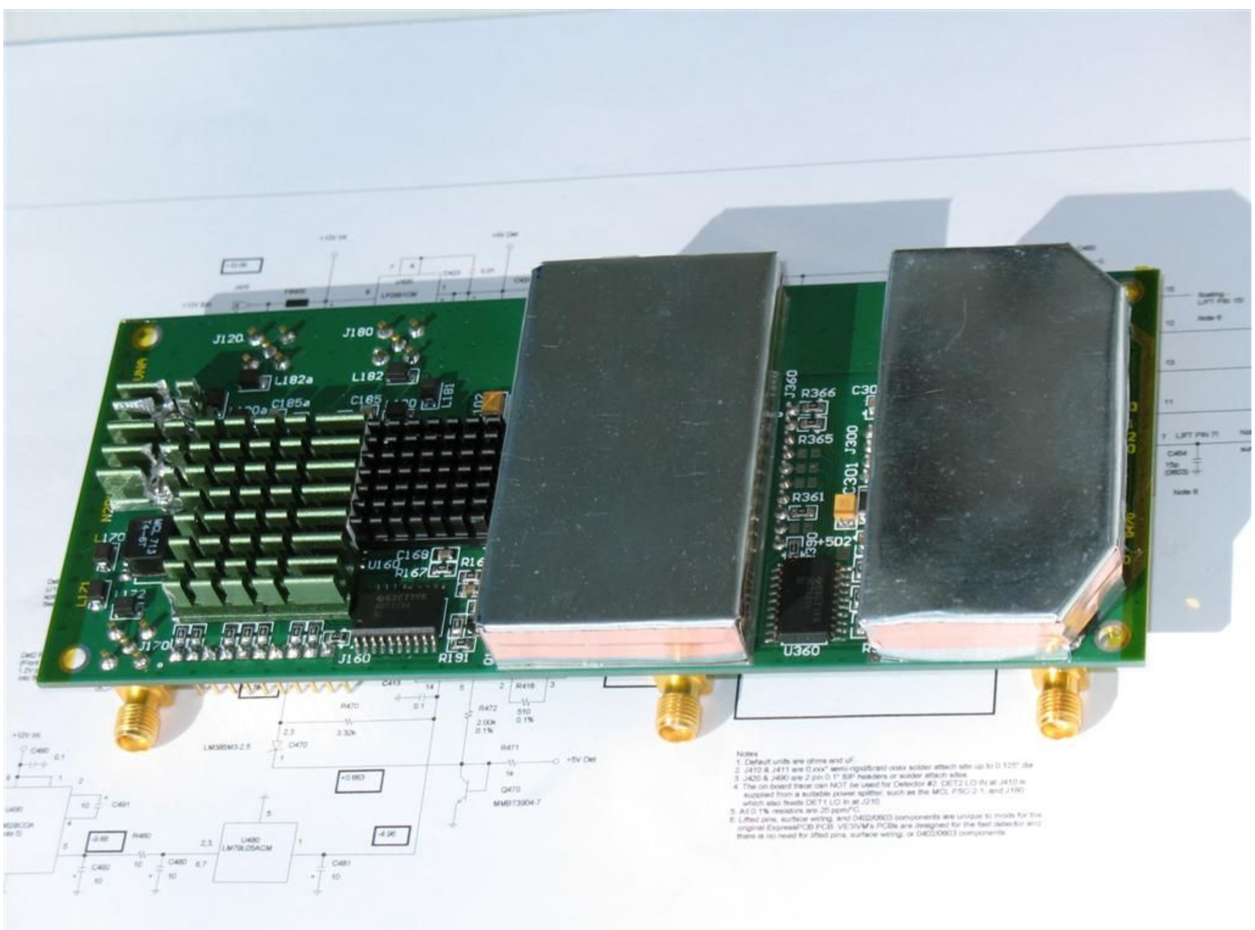
- Galactic sources (Vary from 10-250K)
- Cosmic background of (2K)
- The atmosphere (32K)
- The Sun (300,000K on a quiet day)
- The Earth (290K)
- Man made noise (varies from near 0 to 4,500K in industrial areas)
- Equipment noise (varies by equipment and ambient conditions)



Some noise sources we do not have to worry about. For example, the earth is a fairly strong source, but if we point our antenna patterns upward and separate the antenna from the ground by a ground plane, it will not be as much of an issue. Some noise sources are best dealt with by avoiding them altogether, such as avoiding industrialized areas and not pointing the antenna at the sun.

System Noise and Interference

Unfortunately, the noise present is not only amplified with the signal, but parts of our equipment generate their own noise through RF interference, shot noise, and Johnson-Nyquist noise. Since all of these noise effects are thermally dependent, one effective way to reduce the system noise is to cool the components. Interference can be reduced by shielding the stages that might generate or be susceptible to interference in a shield. This shunts the interfering signal to ground, significantly reducing the effects. These methods only go so far in reducing interference and system noise, which is why it is important to move the signal into a digital format as soon as possible.

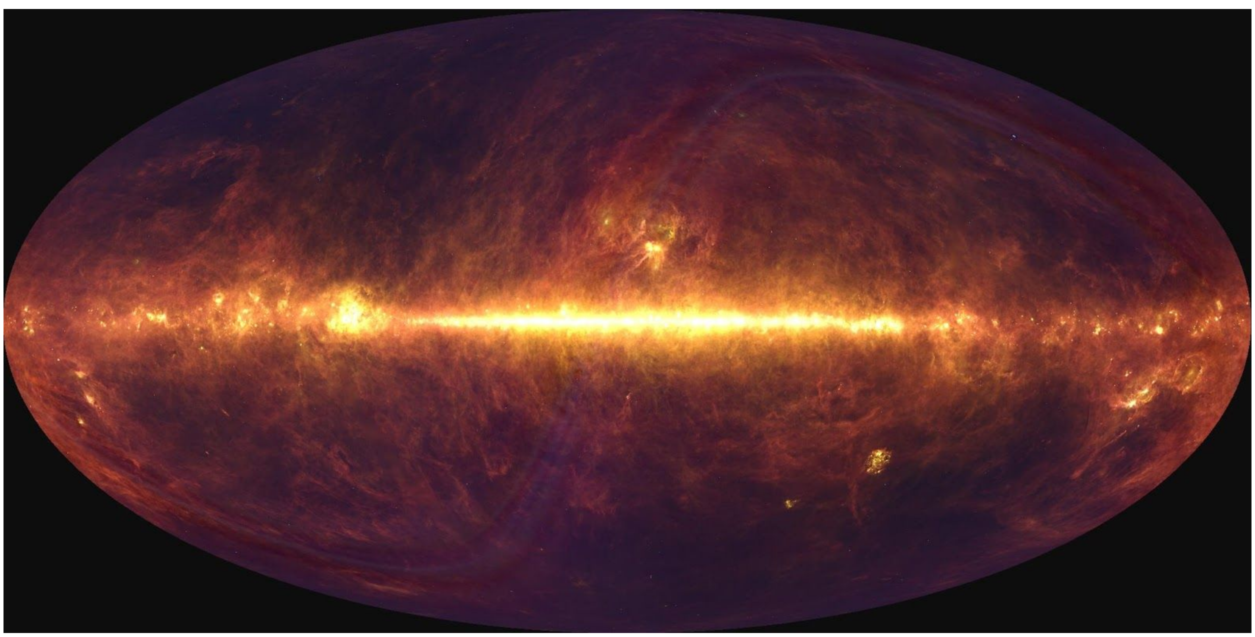


Atmospheric and Celestial Noise Sources

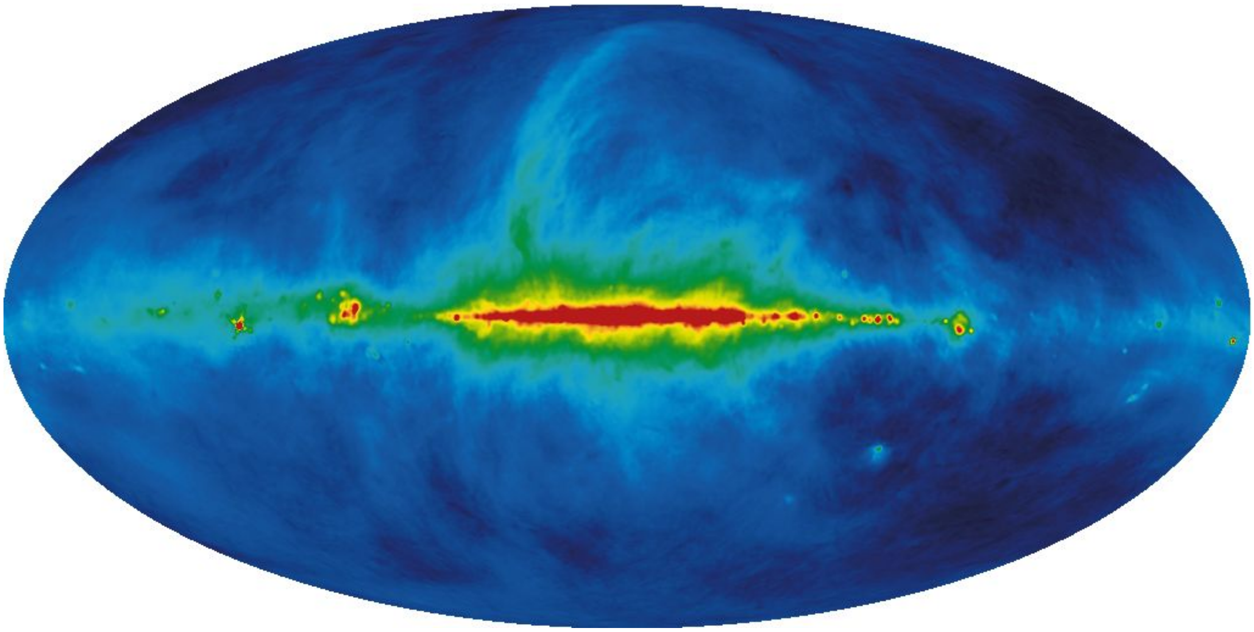
The atmosphere itself can also make noise as the molecules rattle around. While this effect is fairly minimal compared to other noise sources, it adds up, particularly if the signal is coming in at a shallow angle. The lower the angle, the more atmosphere we need to go through, which not only attenuates our signal, but it also adds noise.

For our purposes, we will use 32 Kelvin as the atmospheric noise figure.

As you might suspect, noise from celestial sources (sky noise) varies by what you are pointing at. In this image, three radio wavelengths are rendered by three colors. While beautiful, the powerful radio emissions near the center of our galaxy shining brightly will increase the noise floor, making a weak signal more difficult to pick up.



More specific to our scenario, the this image shows the sky at a frequency of 408 MHz, and 137 MHz is fairly similar. You can see how areas correspond roughly to the composite image. The colors represent the background noise temperature on a logarithmic scale from 10 Kelvin in black and blue to 250 Kelvin in red.

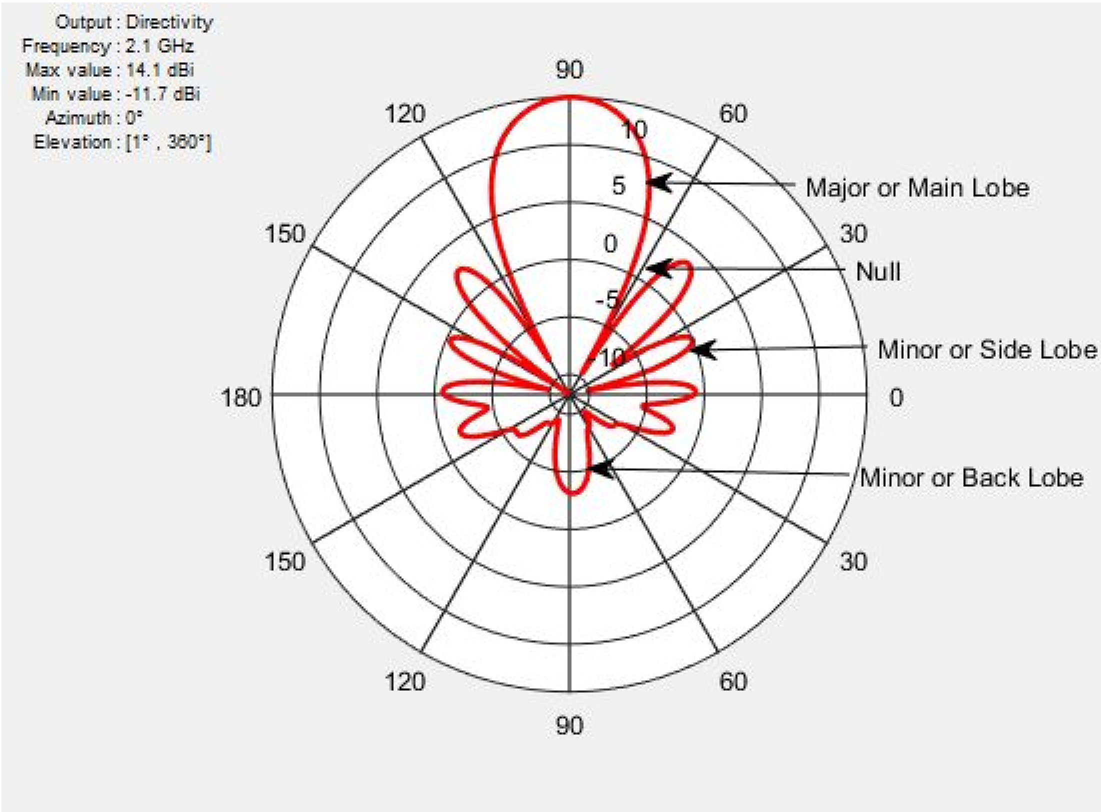


Pointing an antenna at a satellite with the center of the galaxy as a backdrop will increase the system noise by over 3dB. With a weak signal, this could become quite significant, but there is nothing to do for it other than wait for the satellite to move.

For our purposes, let's use 15 Kelvin as our sky noise figure, as this is close to the median.

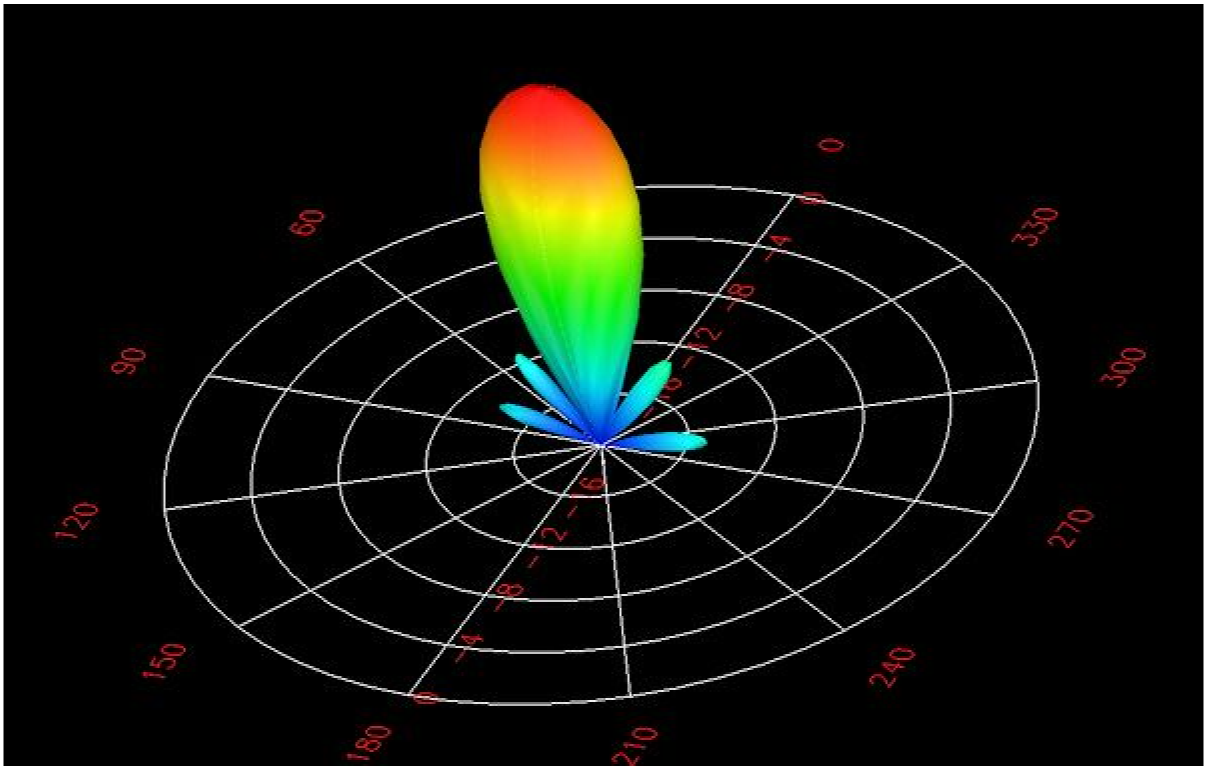
Terrestrial Sources

If we could point a perfect beam at the satellite, we would not have to worry about terrestrial noise sources, but we don't live in a perfect world. Antenna patterns not only have a primary (major) lobe, they also have side and back (minor) lobes as you can see in this plot.



Most likely, one or more of these minor lobes will be pointing at the gro und (290 Kelvin), or worse, at an industrial center (1200 Kelvin), or the computer used to decode the signal (890 Kelvin). Murphy's law being what it is, your neighbor will pick the time for the satellite pass to begin welding his latest metal art masterpiece. This is why antenna selection is so critical; we not only need to make sure that we can pick up the signal, but also *not* pick up the noise.

Antenna efficiency is a figure between 0 and 1 which indicate how much of the signal is coming from the major lobe compared to minor lobes. It factors heavily into the gain characteristics of the antenna. Unfortunately, this figure is not often published since few people understand what this figure represents. It is easier to sell an antenna which yields a 400% boost (+6dB) than saying it has an efficiency of 0.73.

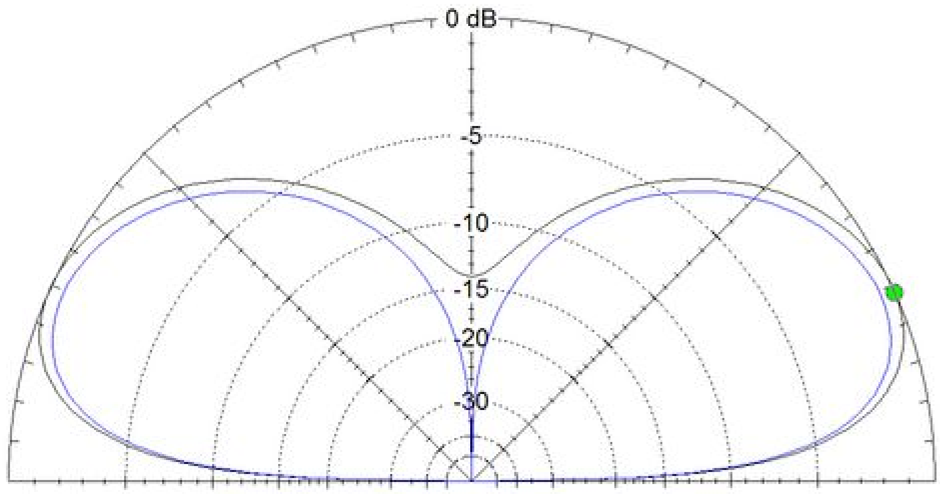


In this example, the antenna has a fairly narrow major lobe and this particular model has an efficiency of 0.88. This means that 88% of the signal the antenna has converted to electrical power is coming from the satellite, the atmosphere, and celestial objects in the major lobe pattern, while the other 12% is coming from the minor lobes.

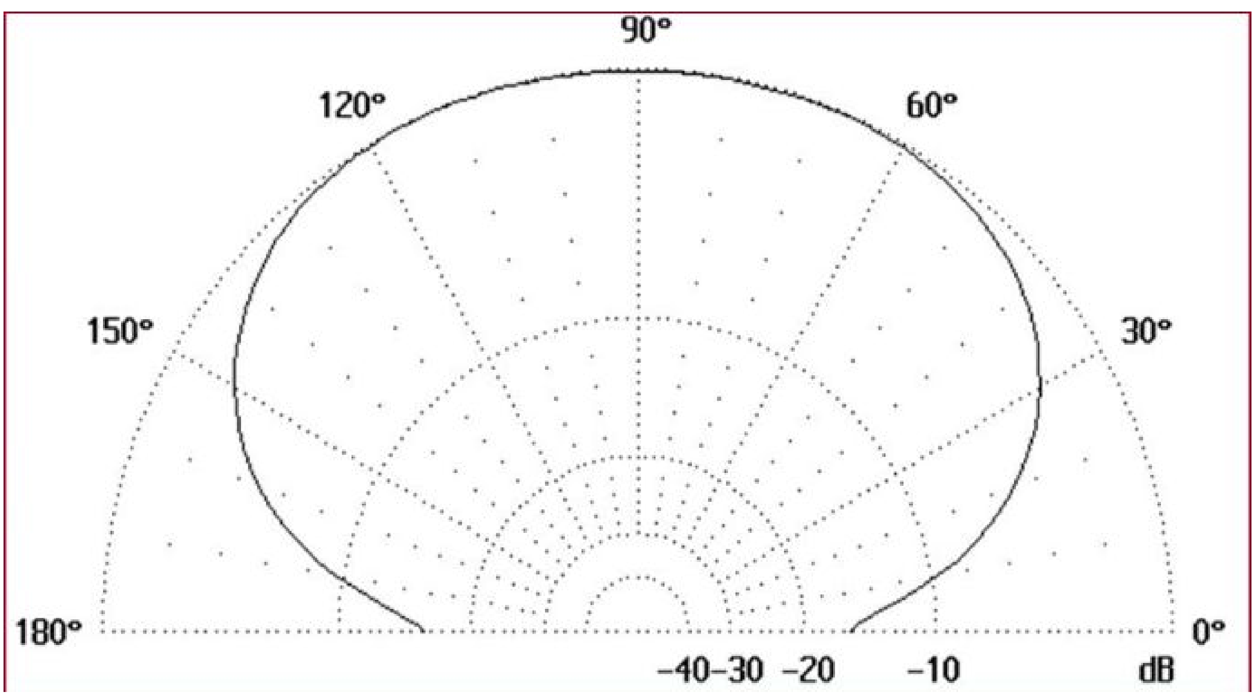
Unfortunately, this includes sources like the industrial area near the ground station, other terrestrial noise and the earth itself in addition to the ever present celestial sources. The noise added to our signal is a function of the average noise temperature picked up on all lobes of our antenna with the gain of the lobe factored in using the antenna efficiency number as the factor. We'll step through that on a future video.

Antenna Selection

We want to be able to pick up NOAA-19 at 60 degrees above the local horizon while rejecting terrestrial signals. We also want the overhead signal, so a top-blind antenna design like this one is a poor choice.

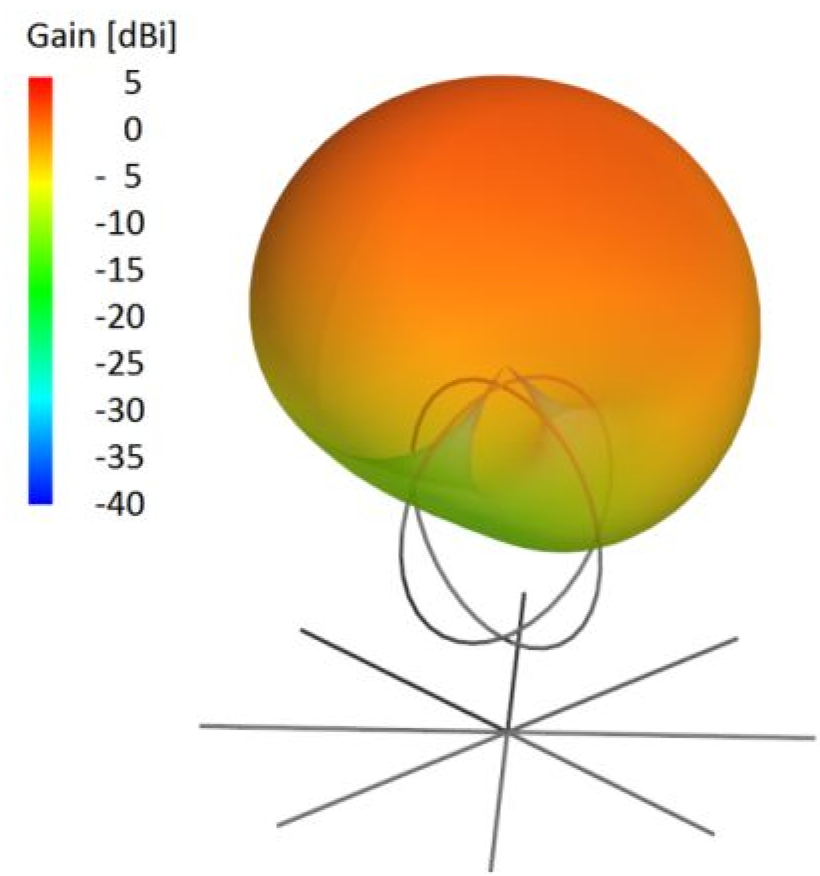


What we need is an antenna with a pattern closer to this:



This pattern would reject much of the terrestrial noise while giving us fairly good signal in our anticipated 120 degree detection arc. What determines the pattern of the antenna is largely construction, so this becomes a process of finding the pattern which matches our use.

There isn't really an antenna pattern library online, so this becomes more of a process of trial and error. Three antennas have the pattern we are after: the eggbeater, the turnstile, and the quadrifilar antennas. The quadrifilar can have higher gain, but is fairly complex to construct. We'll try the cheapest and easiest antenna first. The eggbeater fits this bill, so that is what we will base our math on and build if the math works out.



While the antenna is of a fairly low gain design (+5-6 dB), the lack of any minor lobes makes it very tolerant of noisy environments and easy to figure out the pattern as the satellite flies over.

Conclusion

That's it for the the noise and antenna selection part. Next week we will cover the communication link from the ground station antenna all the way through the receiver. Besides commonly available parts, the equipment we hope to use is the inexpensive RTL2832u software defined radio (SDR) receiver that connects to any modern computer via the USB port.

The unit I will be using is the NooElec NESDR SMArt, which is based upon the RTL2832u and the R820T2 tuner. I ordered it a couple of days ago, and expect it shortly after the 4th of July holiday. For about $30.00 this SDR has some extra bells and whistles that help us bring that signal in, but once we get it all figured out and test, I will build the same ground station using the less expensive to make it work for much less money. I get the feeling that several antenna designs will be made in the course of this video.

If you want to get a jump on things, go ahead and order one online. The software to run this device is generally free and easy to get online for any operating system, and it will become a core component of the ground station receiver we will build. If you do pick one up, make sure it has the R820T or R820T2 tuner, as this combination yields great results.

As far as the software to run the SDR and decode the signal, it all depends on what operating system you are running. I use Linux, and this means that GQRX and GNU radio are some of the tools I use. We'll be using GQRX to receive the signals from NOAA-19 which also works on Macs. If you are a Windows user, have a look at SDR# and HDSDR. All are free. If you have one of the SDR dongles and want to get familiar with running the radio install the software and start exploring

Let's go!

I would like to send out a big thanks to Scott Johnson over at SolarNetOne for the use of a proper video camera and generous donation. This guy and his company are awesome! Right now he is setting up computers for use in Kiribati, helping those folks have access to the internet resources we all take for granted. Do you need a power or networking miracle for anything from a home to sovereign nation? Call Scott at SolarNetOne.

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References

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